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NATO INTERNATIONAL STAFF - DEFENCE SUPPORT DIVISION

ELECTROSTATIC DISCHARGE, MUNITION ASSESSMENT AND TEST PROCEDURES

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NORTH ATLANTIC TREATY ORGANIZATION

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A. GRØNHEIM
Major General, NOAF
Chairman MAS

NATION	RESERVATIONS

RECORD OF CHANGES

Change Date	Date entered	Effective Date	By Whom Entered

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ELECTROSTATIC DISCHARGE, MUNITION ASSESSMENT AND TEST PROCEDURES

1. INTRODUCTION

This document provides supplemental information on the requirements and procedures contained in NATO STANAG 4239. Suggestions on conducting an assessment of the electrostatic discharge (ESD) threat to a weapon system and on performing system verification testing are made. Assessment is based on the construction of a weapon system and the sensitivity of the weapon system and its sub-components to ESD.

Included are suggestions on determining the need for testing, appropriate test hardware configuration, and selection of discharge locations.

Techniques are proposed for use in system verification of ESD simulation hardware. The effect of moisture in the air and on (or just under) the surface of the test item when conducting testing is considered. This section describes ESD simulation techniques used in ESD testing, the use of a standard calibrated load, and the effect of probe geometries. Also described are the band width of the standard load and wave form analysis hardware.

Finally, techniques for assessing test data and the statistical significance of the number of tests conducted on each component is provided.

2. SCOPE

This AOP addresses the assessment of ESD hazards associated with personnel-borne or helicopter-generated threats. Such an assessment may be limited to a paper analysis or could include testing to determine the sensitivity of the weapon system (or associated subsystem) to the helicopter and/or personnel ESD threat.

It is not within the scope of this AOP to address ESD threats associated with the transfer of charges that may be generated on non-conductive weapon system surfaces due to the charge separation associated with the movement of the weapon system (or associated subsystem) with respect to non-conductive pads and packaging in the shipping containers. If such threats are likely to be encountered, then a hazard assessment and possibly testing will be needed for the system.

3. HAZARD ASSESSMENT

3.1 General

An analysis of the weapon system and associated subsystem should be conducted to determine its potential susceptibility to an electrostatic discharge (ESD) event associated with the operations that may be experienced during the life-cycle of the weapon system. This analysis should address issues affecting both safety and suitability for service and should be approved by a recognized national authority. The analysis should concentrate on a review of the firing circuitry, the sensitivity of EEDs and/or electronic subsystems, and reviewing construction details. The review is to include wiring diagrams, materials, and the bonding of grounding systems with conductive bodies.

3.2 Required Data

The following data is required to assess the ESD susceptibility of the weapon system and/or associated subsystem.

3.2.1 Designation

The full designation as to type and design specification of the weapon system or ammunition to be assessed shall be provided.

3.2.2 Drawing Package

A drawing package consisting of, at minimum, wiring diagrams and construction details shall be provided to the organization performing the ESD hazard assessment. The drawing package must identify the location and type of any EEDs and other explosives components that are part of the weapon system to be assessed.

3.2.3 Electro-Explosive Devices

Specific details required on the EEDs used or proposed for use in the weapon system shall include:

3.2.3.1 EED Mk/Mod Designation

3.2.3.2 Electrical Characteristics

Electrical characteristics required include bridgewire resistance (when applicable) and no-fire thresholds for energy, power, current, or voltage levels, as appropriate. These threshold levels shall be defined in percentage of no-fire threshold at a given confidence level. An explanation of how these threshold levels are derived is also required.

3.2.3.3 Results of any prior ESD testing.

3.2.4 Electrical/Electronic Subsystems

Details of all electrical/electronic subsystems associated with the initiation of EEDs or functions the failure of which would result in the weapon system being rendered not suitable for service shall be provided.

3.3 ASSESSMENT CONSIDERATIONS

3.3.1 General

An ESD susceptibility analysis must begin with a review of the life cycle (logistic and deployment configurations) proposed for the weapon system. The review of the life cycle will providei nformation necessary to identify the ESD threat(s) likely to be encountered and the configuration of the weapon system (or subassemblies) likely to encounter the threat.

3.3.2 Configuration

As previously stated, the configurations used for the analysis and/or ESD testing of a weapon system or subassembly shall be determined by the life cycle (logistic and deployment configurations) of the weapon system. All configurations of the weapon system and associated subsystems where the ESD threat may be sufficient to affect the safety or suitability for service shall be addressed during the ESD assessment.

3.3.3 Component Sensitivities

To assess the ESD sensitivity of a weapon system it is necessary to obtain construction details on the "configuration under consideration" and ESD sensitivity information on specific components e.g., associated EEDs, pyrotechnics, propellants, high explosives, critical electronic subsystems and other components. These construction details and diagrams must provide sufficient information to determine the shielding effectiveness of the integument, the size and construction of any apertures in the configuration (or shipping container where applicable), the bonding of conductive bodies and their interconnection with the electrical ground reference.

Review of the construction details and schematics will identify locations where bonding and shielding ensure that potentially sensitive components would not be affected. Also, those locations and configurations should be identified where an ESD threat exists to a component that is critical for safety or suitability for service. Any previous ESD sensitivity test data should be reviewed in determining whether testing may be necessary.

The ESD threat associated with the charge generated on non-conductive weapon system integuments is not within the scope of this document. However, an ESD assessment should take this threat into consideration whenever non-conductive transport cases are used.

3.3.4 Transient Suppression

Once the shielding effectiveness of the "equipment under consideration" has been determined, it is necessary to examine the effect due to direct current injection. For those integuments which are conductive, the direct current injection threat is minimized for the threats within the scope of this document. Weapon systems and their associated subsystems which are not constructed with conductive surfaces must be analyzed to ensure that the attachment point of an ESD event will not result in structural damage.

Direct current injection associated with an ESD event may be minimized by the use of transient suppression hardware. The effectiveness of the transient suppression hardware installation must be analyzed for its response to a broadband electromagnetic pulse, such as that produced by an ESD event. It is stressed that the installation of transient suppression hardware does not necessarily infer that the item is ESD insensitive.

3.3.5 Decision to Test

On the basis of the previous considerations it must be decided if testing is necessary. A decision that testing is not necessary must be approved by the responsible National Authority.

4. TESTING CONSIDERATIONS

4.1 GENERAL

This section provides recommendations on items of concern when one has determined there is a need for ESD testing. Recommendations are made on the preconditioning of the test item, the selection of discharge locations, the energy transfer techniques used, the shape of the electrode, and the number of items required for testing.

STANAG 3516 addresses the techniques for testing avionic systems which may be subjected to personnel handling under conditions which are much less severe than those required by STANAG 4235. The techniques, however, can be applied to the higher levels of discharge voltage required by STANAG 4235.

4.2 PRECONDITIONING

STANAG 4239 requires that the test item be preconditioned for a minimum of 24 hours to a temperature of 23 $\pm$ 10 °C. Some weapon system components have been found to be more sensitive to an ESD threat at lower temperatures. Should the life cycle of the weapon system or component include exposure to low temperatures, it is recommended that the item be test at those temperatures when it is felt that such an environment may make the item more sensitive to electrostatic build-up or discharge.

STANAG 4239 states that ESD testing shall be conducted at relative humidities of less than 60 percent where practicable. It also recommends that the test item be preconditioned to such an environment for a minimum of 24 hours. It is recommended that ESD testing be conducted at as low a relative humidity as can be reached. If the test item has not been preconditioned to a low relative humidity environment, the water in the air may condense on (or just below) the surface of the test item. Such a moisture layer may act as a partially conductive layer that may act to protect the test item during the testing. Under extended exposure to a low relative humidity, this partially conductive layer is not likely to be present. As a result, it is possible for a munition or associated system to be sensitive when preconditioned in a low relative humidity environment and not be sensitive to the same threat if the item has been preconditioned in an environment with greater than 60 percent relative humidity.

4.3 SELECTION OF DISCHARGE LOCATIONS

The selection of discharge locations should be made from a review of the Hazard Assessment (which is discussed in Section 3). The test points chosen must be based on those locations identified to be potentially sensitive to either direct penetration or excitation of the test item with internal distribution of the energy.

4.4 ENERGY TRANSFER TECHNIQUES

4.4.1 Electrode Geometry

The geometry of the discharge probe is an important aspect in the efficiency of the threat simulation hardware in the transfer of the energy stored in the capacitance(s). The lower the radius of curvature (i.e., the sharper the point), the more concentrated the electric field will be on the tip. Once the energy stored in the capacitance of the threat simulation hardware is transferred to the discharge probe, ionization will occur. The sharper points will experience more leakage at lower voltages because of the concentration of the electric field lines. Since a ball-type electrode with a large radius of curvature will result in less ionization, it is the recommended geometry for the discharge probe.

In real life, the discharges may occur from a wide range of electrode configurations. The electrode geometry chosen for testing should be based on the threat that may be experienced and the energy transfer technique to be used. It may be necessary to use a different electrode configuration for the purposes of calibration to allow comparison of the threat simulation hardwares from one test agency to another. Section 5 provides a more detailed discussion on this subject.

4.4.2 Triggering Techniques

There are several techniques that have been used in the past for the triggering of the simulated ESD threat. Those most often discussed are: (1) an approaching probe, (2) a discharge across a gap, and (3) a salient discharge.

Two techniques have been used in simulating the ESD threat produced by external helicopter transport. One technique is to charge the test item to the test voltage (such as 300 kV) and to then bring a grounded wand into the proximity of a point on the test item where a discharge is desired. Once the grounded wand approaches the charged test item, a spark discharge will be generated. The exact location of the source of the spark is difficult to control using this procedure.

The second and most popular technique is the use of a Marx Generator. In these cases, a salient electrode connected to the test item at the desired discharge point is often used. The triggering of the spark is provided by the breakdown between the stages of the Marx Generator. The discharge location can be controlled very easily with this type of procedure.

Another example of the use of the approaching probe technique is the case where the probe is driven (by electric motor) toward the test item when conducting testing to the personnel-generated ESD threat. The energy is transferred to the probe immediately prior to the initiation of movement. In this case, the approach velocity is well controlled. However, the distance between the probe and the test item may not be repeatable.

Gapped discharges are often specified by test agencies because they are more exemplary of the actual events. The spark can produce both electrical and mechanical damage whereas a salient discharge will produce only electrical damage. However, there can be a large variation between one test stimulus and another because of the wide variation in the energy lost in the ionization of the gap. The use of salients with equipment which provides the spark gap internally will provide more control over the coupling of the threat to the test item and in discharging to the test points selected.

4.5 NUMBER OF TEST SAMPLES

The number of test samples used is critical in the assigning of relevance to ESD test results. Because the ESD testing is go/no-go in nature, the results can only be examined statistically. In addition to the normal statistical variation of such type of testing, the confidence in results of tests of explosives components is decreased by the fact that there is a significant variation in many components from lot to lot. Accordingly, little confidence should be given to the fact that one test item survived a test threat. Such a sample size can be seen from Table (1) to correspond to the item being 50 percent reliably insensitive to such a threat (with a 50 percent confidence level). As can be seen in the table, when the number of samples used is 10, the confidence level goes to 80 percent and the reliability that the item is insensitive goes to 85 percent. For 22 tested items, the confidence level goes to 90 percent with a 90 percent reliability.

5. SIMULATION HARDWARE CALIBRATION

5.1 GENERAL

STANAG 4239 requires that the threat simulation hardware used in the testing of a weapon system to the ESD threats discussed in the STANAG be calibrated prior to the start of testing and at the completion of such testing. The following sections discuss acceptable procedures that could be used in the calibration of threat simulation hardware.

5.2 CALIBRATED TEST LOAD

The test load, as shown in figures 1A & 1B, shall be coaxial in design with a resistance of 1 ohm between the center conductor and the ground shield. The output of the threat simulation hardware used in testing to the personnel-generated ESD threat should be recorded when discharged into a calibrated test load. The resistance of the test load should be linear over the frequency range of DC-to-100 megahertz.

There is no calibrated test load proposed for use in testing to the helicopter external transport threat. The test load used when recording the calibration waveforms must be described in the test report.

5.3 ACCEPTABLE CALIBRATION PROCEDURES

5.3.1 General

The calibration procedures described below may be used in the calibration of threat simulation hardware used in testing to the personnel-generated and external helicopter transport threats.

5.3.2 Personnel-Generated Threat Calibration Procedure

The threat simulation hardware output electrode should be touching the center conductor of the calibrated test load. Waveform measurements should be made at both positive and negative polarities at 10, 15, 20, and 25 kV levels. The output of the calibrated test load shall be fed (using 50-ohm terminators and/or attenuators, as applicable) directly into a data acquisition system which has a frequency range of DC-to-100 megahertz.

5.3.3 External Helicopter Transport Calibration Procedure

The calibration procedures used for hardware developed to simulate the external helicopter transport threat may be developed by the agency conducting the testing. The calibration procedures used should be described in the test report along with the simulation hardware output waveforms recorded during the calibration procedures.

TABLE 1

NUMBER OF TESTS WITHOUT FAILURE REQUIRED TO DEMONSTRATE RELIABILITY AT VARIOUS CONFIDENCE LEVELS

Reliability	Confidence Level (%)						
(%)	50	60	70	80	90	95	99
99	69	92	120	160	229	298	459
95	14	18	24	31	45	58	90
90	7	9	12	15	22	29	44
85	5	6	8	10	15	19	29
80	3	4	6	7	11	14	21
75	3	4	5	6	8	11	16
70	2	3	4	5	7	9	13
65	2	2	3	4	6	7	11
60	2	2	3	4	5	6	9
50	1	2	2	3	4	5	7

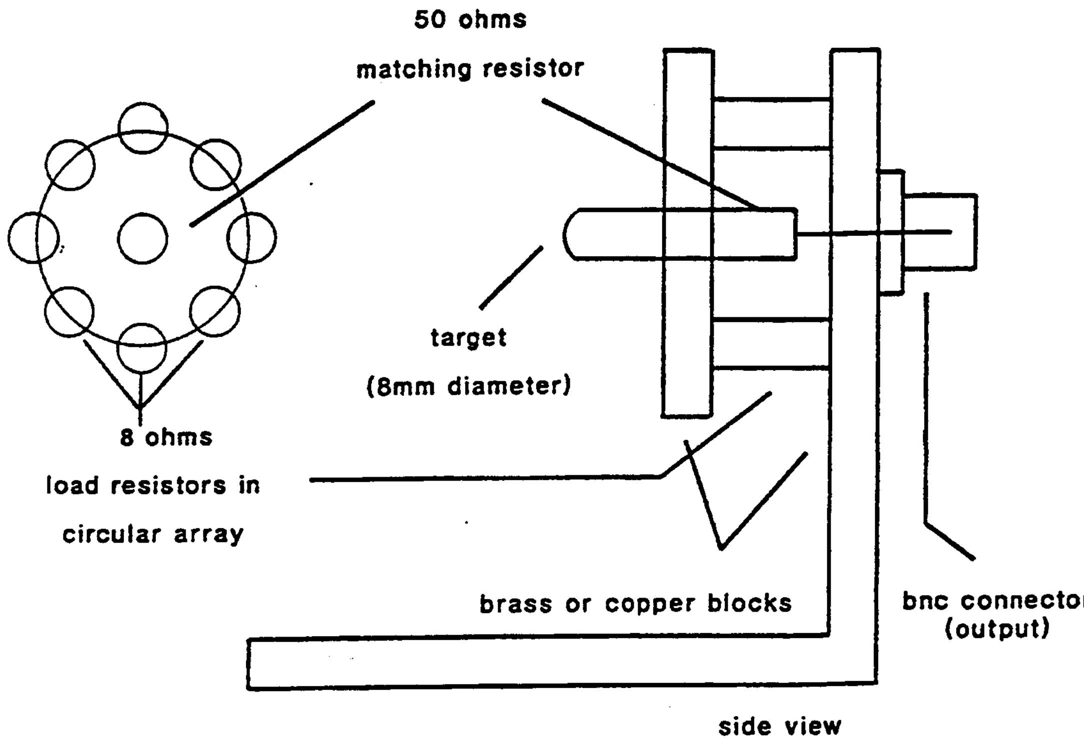

Figure1A: ESD STANDARD LOAD DESIGN

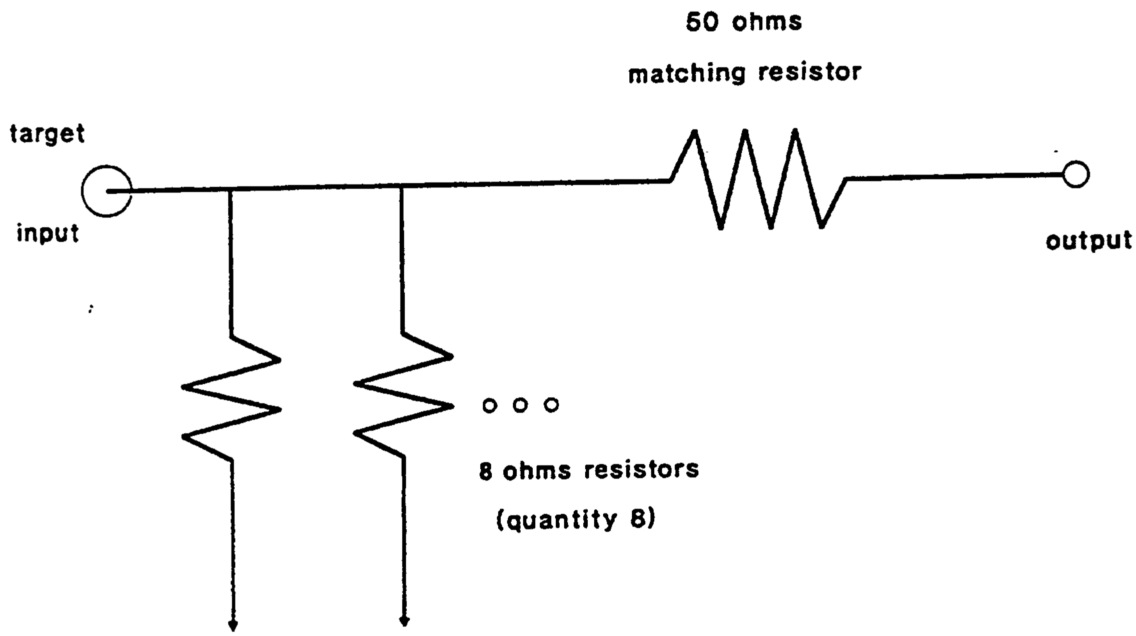

Figure1B: ESD STANDARD LOAD ELECTRICAL MODEL